hydrofoil. These tip hydrofoils serve to increase the aspect ratio of the main hydrofoil by increasing its span and changing the flow pattern near each end. The tip hydrofoils can be angled up or down relative to the main hydrofoil, and can be either fully wetted or have a closed cavity on one or both surfaces. At least one surface of at least one tip hydrofoil has a closed cavity for reducing drag. The tip hydrofoils can also be placed at an angle of attack to the flow in order to generate a vortex that is opposite in direction to the usual tip vortex generated near each end of a main hydrofoil to reduce induced drag.--

REMARKS

The Applicant appreciates the Examiner's thorough review of the patent application and the prior art.

The Examiner's detailed comments on pages 2-8 of the Office Action are appreciated and have been satisfied by incorporating the language of the claims in the written description and by numbering in the drawings, where appropriate.

A permeable membrane, as described in Claim 11, is described in the specification at page 8, line 17.

A fence comprising a fluid jet, as described in Claim 19, is described in the specification at page 9, line 23.

Concave surfaces ahead of the trailing edge, as described in Claim 29 (not 30 as mentioned by the Examiner), are already described on page 6,line 32 and in figures 17-19.

Propulsion drive shaft located in a strut, as described in Claim 105, is described on page 1, line 32 and is shown in figure 1.

Low gearbox contained within a pod, as described in Claim 116, is described on page 4, line 32.

With regard to paragraph 7, beginning on page 8:

"Local" is known to refer to angle of attack at a particular point.

"Saw-tooth-like" does not fall within MPEP 2173.05(d), which deals with "such as" or "for example."

"The body has a yaw angle" is acceptable. Yaw is known to be the angle from straight ahead.

"Sides that deviate from side lines" correctly describes the structure.

Reconsideration and allowance of claims other than accepted Claims 74-78 is requested. Claims 1-61, 125-142 and 152-174 describe an important new invention that is not included in Lang '829. The present invention is described in the claims. This new invention further reduces drag on a hydrofoil with closed cavities by minimizing, or approximately minimizing, a cavity contact angle. The cavity contact angle is minimized in a desired cavity closure region to increase cavity area. For example, if cavity area coverage on a hydrofoil is increased from 75% to 87% by using this new idea, frictional drag is reduced by about a factor of 7.7 = 1/(1-0.87), instead of a factor of 4.0 = 1/(1-0.75).

This new invention seems simple, but is not, and requires a non-typical design approach. For example, a typical design approach would be to make the cavity contact angle exactly zero at a desired cavity closure point. Unfortunately, the cavity would not close at the desired point and would instead close well ahead of this point. This result occurs for the following reasons.

As one might expect, tests show that cavity length typically increases as a gas flow rate increases. Tests also show that the gas flow rate increases with cavity contact angle. Logic then dictates that if a surface is shaped so that, for example, a desired minimum cavity contact angle lies midway between stations A and B where the cavity contact angle is larger by 4 degrees. As a gas flow rate increases, a cavity will eventually close at station A, but will then jump to station B

as the gas flow rate further increases. The cavity will avoid closure at the desired cavity closure station because the gas flow rate is too large to permit the cavity to remain at this station. There is a simple solution to this problem.

To minimize a cavity closure angle at a desired closure point, the surface ahead of the desired closure point should be designed so that cavity length increases with gas flow rate until the desired cavity closure point is reached. If done optimally, the cavity closure angle is minimized at the desired cavity closure point. Beyond this closure point, cavity closure angles should be designed to increase in order to provide a design margin in gas flow rate before the cavity reaches the trailing edge.

The inclusion of this new invention distinguishes the following claims from Lang '829:

Claims 62-73 contain a new invention that reduces the wetted surface of a hydrofoil nosepiece and smoothes the walls of an upper cavity to further reduce the drag of a hydrofoil with closed cavities. In its simplest form, this new invention has a flat plate nosepiece inclined at a large angle to the water flow, such as 60 degrees. It is described as a wetted nose section on the lower surface that extends from the leading edge rearward to a span-wise lower discontinuity. This causes a lower boundary layer to separate from the lower surface and form a lower cavity extending rearward along the lower surface. The nose section has an upper surface discontinuity causing an upper water boundary layer to separate from the upper surface of the hydrofoil and form an upper cavity rearward, extending along the upper surface. Such a plate cuts the wetted surface area of a nosepiece in half or more.

Claims 79-100 describe a new invention that relates to a surface-piercing strut or hull that includes a horizontal fence to separate an upper superventilated cavity from a lower closed cavity.

This permits the pressure in the lower cavity to be different from atmospheric pressure. The new invention gives a designer flexibility in selecting widths and lengths in the lower region and changing pressure with speed to minimize drag at speeds other than the design speed.

Claims 101-104 include a new invention related to Claim 65 of Lang '829 that covers hulls having an air-filled cavity on each side, and a separate cavity on the bottom surface. The new invention adds vertically extending discontinuities, such as wedge-like protuberances, between the bow and stern of the hull on each side surface to keep water from re-contacting the hull in off-design conditions, such as operating in waves or at speeds other than a design speed. Significant reductions in drag can result when operating in waves or at speeds other than the design speed.

Claims 105-124 describe an invention different from Lang '829 in that they permit a vee-shaped foil with a sweep of at least 45 degrees to be used for partially lifting a hull above water.

Claims 108-110 relate to ventilating propulsors not covered in Lang '829.

Claim 117 is not included in Lang '829, and covers the use of an underwater sound transmitter attached to the craft for transmitting a sound beam forward of the craft for frightening sea animals away from a path of the hydrofoil.

Claims 122-124 are not included in Lang '829, and cover new inventions related to the use of vented propulsors of various kinds in conjunction with a low drag hydrofoil craft.

Claims 143-144 cover a new invention, not included in Lang '829. This new invention provides a simple way to initiate a cavity and one that has great potential. The idea is to attach a plate perpendicular to the flow, outward about 90 degrees from a surface, to initiate a cavity. Those skilled in the art would not have considered this idea because they would have tended to believe that such a plate would add too much drag. In the case of the invention presented here, that

utilizes gas cavities for drag reduction, that belief would not have been true.

Claims 152-181 describe an invention that is not mentioned in Lang '829, because these claims extend the new invention in Claim 1 to include the additional invention of increasing the cavity contact angle in the surface behind the desired termination region. A description of the benefits of this additional invention is included in the above discussion of Claim 1.

Claims 175-181 are method claims not mentioned in Lang '829 that are similar to Claims 62-73 discussed above. These claims are very important. They relate to replacing a normal nosepiece with a single, angled plate that initiates both upper and lower cavities, reduces wetted area and smoothes the upper cavity wall.

Claims 193-201 cover new inventions. The new inventions are important for use with smaller versions of low drag hydrofoil craft where the main hydrofoil is fully submerged and where automatic control may not be feasible. Not mentioned in Lang '829 is a bow lifter that is positioned near a front of the craft for stabilizing the craft in at least heave and pitch conditions. With stabilization in pitch and heave, it is possible to either manually control roll, or to automatically control roll with a fairly simple system. Typically, heave and pitch are difficult to control, either manually or automatically.

Claims 202-203 describe an invention not mentioned in Lang '829. A bow lifter for a hydrofoil craft has a fully submerged dynamically lifting v-hydrofoil in plan view whose leading edges are swept at least 45 degrees. Claim 203 includes a swept back v-hydrofoil in plan view having negative dihedral and foil tip regions that pierce the water surface at a design speed.

Claims 214-216 cover a new invention that is not mentioned in Lang '829 and comprise a method for dynamically stabilizing a low drag, vented hydrofoil craft in roll. This new invention stabilizes

roll by using two lifting struts that are angled to the vertical. Claim 216 provides full dynamic stabilization by adding a bow lifter for stabilizing the craft in heave and pitch.

Claims 217-220 cover another new invention that is not mentioned in Lang '829. An above-water portion of the craft provides aerodynamic lift to augment hydrodynamic lift from a low drag hydrofoil and makes use of water proximity for further increasing the aerodynamic lift by using a surface effect. Claims 218-220 add an aft air stabilizer and provide for sweeping the leading edge of the foil back or forward at least 45 degrees to help prevent cavitations at higher speeds.

Nothing in Lang and Marentic would have suggested their combination in the way proposed by the Examiner.

Claims 52, 54, 55, and 145-151 point out a series of parallel ridges placed in the cavity closure region. Nothing in Marentic would have suggested placing ridges in a cavity closure region.

Nothing in Marentic would have suggested angling the ridges, as pointed out in Claims 52 and 146.

Nothing in Marentic would have suggested grooves in an upper and lower cavity closure region as in Claim 54.

Nothing in Marentic would have suggested the U-shapes of Claims 55 and 151, the height less than cavity thickness of Claim 147, the fitting attached in the cavity closure region of Claim 148 or the sides deviating from straight lines as in Claim 150.

In the case of Wippel '071, air cavities are trapped in large grooves or channels 83, formed between ribs 84, as seen in Wippel's Figure 3. These grooves or channels, by definition, must extend above the cavity. Therefore, Wippel does not anticipate Claim 145 because he cannot

make use of the claimed invention with his geometry.

In the case of Barkley, the invention provides a simple way to control lift and roll of a fully submerged hydrofoil by increasing the dihedral of the outer regions of a lifting hydrofoil that are normally placed at a dihedral angle of 0 to 10 degrees. Barkley does not teach the addition of a tip hydrofoil to each end of a hydrofoil for reducing induced drag and for changing the flow pattern near each end of the hydrofoil as in Claims 56-58, 170, 171, 173, and 174. Nor does Barkley teach the use of a surface-piercing, upward-angled tip region at each end of a lifting hydrofoil, for attachment to an above-water hull as in 204-209; nor does he teach the use of a lifting, surface-piercing, upward-angled tip region at each end of a lifting hydrofoil for dynamic stabilization as in Claims 210-213.

Each of the claims points out new and non-obvious features of the invention.

The detailed description incorporates the language of the original claims.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached pages are captioned "**Version with markings to show changes made.**"

CONCLUSION

Reconsideration and allowance of all claims are respectfully requested.

Respectfully,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE.

In the Specification

On page 5, after line 5, a new paragraph has been added as follows:

--A debris cutter is positioned at an intersection of the body and the hydrofoil. The at least one horizontal drive shaft includes at least one set of counter-rotating drive shafts connected to the propulsion drive shafts and at least one set of counter-rotating propellers attached to the at least one set of horizontal counter-rotating drive shafts. A set of anti-swirl vanes is attached in line with the at least one propeller on either side of each propeller.--

Paragraph beginning at line 6 on page 5 has been amended as follows:

-- Rudder 10 in each aft strut 5 helps to steer the craft. Banking the craft into a turn by using flaps increases turn rate, and minimizes craft side force. Hinges 15 and retractors, connected to the hydrofoil and to the hull, retract the hydrofoil and permit the hydrofoil to retract rearward and upward. Sonar device 16 helps to detect underwater obstacles that lie in the path of the craft, and can also serve to generate forward-projected sounds to frighten or urge sea animals away from the path of the craft.--

Paragraph beginning at line 10 on page 5 has been amended as follows:

-- An automatic control system 201 is connected to outboard flaps 17 and inboard flaps 18. Outboard trailing edge flaps 17 serve to control craft roll and pitch, and together with inboard flaps 18, serve to control craft height. Fences 19, wetted pods 12, and wetted region 20

serve as fences to separate adjacent spanwise cavities on the hydrofoil in the case where the hydrofoil is supplied with gas cavities to reduce drag. ~~Plural jets 203 supply gas to each adjacent cavity. Bearings and gearing are provided for the drive shaft. Gas ducting along the drive shaft serves to cool the bearings and gearing.~~ Projection 21 on the underside of hull 2 at the center helps to reduce forward strut height, and to cushion bow impacts when operating in large waves.--

Paragraph beginning at line 15 on page 5 has been amended as follows:

-- A sweptback v-hydrofoil that is placed at a small angle of attack can appear to have a small negative dihedral 22, or it can be designed for a negative dihedral; in either case, it will appear somewhat as shown in Fig. 3. Alternatively, for dynamic reasons in some cases, a v-hydrofoil might be designed with a positive dihedral 23, as shown in Fig. 4. ~~The angle of attack reduces towards each tip.~~--

Paragraph beginning at line 21 on page 5 has been amended as follows:

-- Fig. 5 illustrates a hydrofoil 25 whose sweep is reversed from that of hydrofoil 3 in Fig. 2. From the viewpoint of foil sweep theory, little difference exists whether a foil is swept forward or back. ~~The hydrofoil resembles a delta foil.~~--

Paragraph beginning at line 19 on page 6 has been amended as follows:

-- A tail flap 29 is shown in Fig. 6 in its neutral position, and is shown deflected in Fig. 7. Note that the location of the closure points, 42 and 43, for the longer cavity on each surface has

not appreciably changed, indicating that the flap can be deflected without risk of the longer cavities lengthening beyond the trailing edge, especially if the flap is long enough. If necessary, a flap chord can be increased when the flap is deflected. Placing a concave surface just ahead of the trailing edge on each side of the flap 29 will increase the cavity closure angle in the region ahead of the trailing edge to help to ensure that the longer cavities will not close behind the trailing edge.--

Paragraph beginning at line 32 on page 6 has been amended as follows:

-- The special hydrofoil shape in Fig. 10 shows promise for even-greater frictional drag reduction because its only wetted surface areas are the lower surface of the nosepiece 44 and the upper surface of the trailing edge flap. Here, the upper surface is covered with closed cavity 32, and the lower surface is covered with an open, superventilated cavity 48 that closes behind the trailing edge at 49. This hydrofoil design should have very low frictional drag if the cavity merger angle at 49 is made small. Trailing edge regions have removable sections.--

Paragraph beginning at line 4 on page 7 has been amended as follows:

-- The shape of a wetted hydrofoil nosepiece can be varied to change upper and lower cavity shapes, assist in controlling lift, and to reduce drag. For example, the angles of the upper and lower surfaces of wedge-shaped, flexible plate 58 can be independently controlled, controlling geometry of a hydrofoil cross-section, as shown in Fig. 11, by changing the length of actuator 60 which is attached between rigid hydrofoil center plate 55 and rigid nose plate 59 to deflect the flexible v-plates 56 and 58 either outward or inward. The lower part 57 of the nosepiece can be

controlled similarly. An automatic control system 201 is provided for controlling the at least one nose flap for changing local hydrofoil lift.--

Paragraph beginning at line 14 on page 7 has been amended as follows:

-- Because cavity number K increases as speed reduces, cavities tend to be shorter and thicker at lower speeds. Therefore, to reduce frictional drag at lower speeds, it is necessary to change cavity shape by either changing hydrofoil geometry, hydrofoil angle of attack, gas flow rates, cavity pressures, or combinations thereof. Various ways of changing hydrofoil geometry and hydrofoil pitch or angle of attack have been discussed. Typically, for a given hydrofoil geometry, a change in gas flow rate will provide an accompanying change in cavity pressure and shape. Thus, the gas source pressures and flow rates must be adequate to supply gas to the cavities under all of the desired operating conditions. Control of gas flow into the cavity is accomplished with a pressure of the gas source and the size of the openings. A take off mode controller 205 is provided for supplying additional gas to the cavity on the lower surface for permitting the cavity to extend beyond the trailing edge for increasing hydrofoil lift.--

Paragraph beginning at line 21 on page 7 has been amended as follows:

-- In most hydrofoil designs, the cavity pressure on the upper surface is less than atmospheric pressure, in which case the upper cavity gas can be air that is drawn from the atmosphere without using an air pump. If the upper cavity pressure is low enough, then a turbine can be placed in the associated air duct to generate power. A generator 207 is connected to the craft, and air supplied to the cavity on the upper surface at a pressure lower than atmospheric

pressure is used to generate power in the generator. Typically, the pressure on the lower surface of a hydrofoil is greater than atmospheric, in which case the gas, such as air, must be pressurized using a pump. However, in some cases, hydrofoil speed and geometry is such that the pressure on the lower surface of a hydrofoil, although greater than the pressure on the upper surface, can be made less than atmospheric pressure, in which case, no pump is needed and atmospheric air can be used.--

Paragraph beginning at line 29 on page 7 has been amended as follows:

-- For all lifting hydrofoils, the lower cavity must be at a higher pressure than the upper cavity. Consequently, there may be design cases where the simplest and best solution is to supply gas only to the lower cavity, and then duct some of the gas into the upper cavity. One such way is shown in Fig. 14 where gas from a lower cavity is passed through duct 63 to an upper cavity using orifices 64 and/or 65 to meter, or restrict, the gas flow rate. These orifices, restrictors, or limiters could be valves, or ducts 63 could be made small enough to act as a restrictor, or limiter, to meter the gas flow rate without using valves or orifices. A gas flow restrictor 209 communicates with each gas flow releaser for ensuring that each cavity closes ahead of the trailing edge.--

Paragraph beginning at line 7 on page 8 has been amended as follows:

-- In some cases, it is desirable to replace nosepieces, including the case where a nosepiece is damaged. The various kinds of nosepieces shown in Figs. 11-14 can be attached by various well-known methods to permit them to be removable. Leading edge regions have sections 211

that are replaceable.--

Paragraph beginning at line 13 on page 8 has been amended as follows:

-- The hydrofoil cross section in Fig. 17 again shows strut ducts 71 and 73 to bring gas into hydrofoil duct 69 for ejection into upper surface cavities, and into duct 70 for ejection into lower surface cavities. In this case, valves or holes 78 and 79 meter some of the gas into adjacent spanwise ducts for distribution to other cavities located at other spanwise stations along the hydrofoil span. The gas passes through restrictor permeable walls 72 and 74 at the forward ends of the hydrofoil ducts, through slots at the front end of the upper and lower hydrofoil plates, and into the upper and lower cavities. The upper and lower surfaces of the hydrofoil are said to be substantially, or essentially, continuous in spite of the small slot aft of the nosepiece through which gas is ejected. To provide greater strength, if needed, the hydrofoil can be made solid in the mid and aft section, as shown in Fig. 17. If it is desired to remove gas from a hydrofoil cavity on one or both sides, and recycle it, then a suction inlet and gas pump, such as 75, 76, can be installed where the gas is returned by line 77 to gas duct 69 for recycling. At least one gas remover 75 is mounted near the trailing edge for removing gas from near an aft end of at least one of the cavities. A water separator 213 is connected to the at least one gas remover for separating water from the removed gas, and for recycling the removed gas.--

Paragraph beginning at line 7 on page 10 has been amended as follows:

-- Fig. 24 is a cross section of the upper region of the strut shown in Figs. 23A and B. Tail flap 122 is used to control strut side force for turning. The tail flap can either be deflected in the

normal steady-state manner out a desired flap angle, or it can be deflected out to a fixed angle and back at a moderate frequency, sometimes called a "bang-bang" control. At least one adjustable trailing edge flap 122 is a trailing edge region of the body that extends ahead of the trailing edge over at least a portion of the trailing edge. The flap is deflected for controlling side force. Optional nose flap 135 can be deflected outward to move cavity 136 outward, if needed, to keep the cavity from wetting the strut under certain operating conditions. Alternatively, outward steps 138 can be placed on the strut sides to deflect cavity 123 away from the strut at lower speeds, or in waves, if needed. At least one additional discontinuity 138 on each side in the upper region is positioned aft of the discontinuity near the leading edge. A nose flap 135 is positioned on each side of the body. Each nose flap has a trailing edge that provides a discontinuity on that side. Each nose flap extends along at least a portion of a span of the body and each nose flap individually pivots outward from the body about an axis that lies close to the leading edge.--

Paragraph beginning at line 18 on page 11 has been amended as follows:

-- Another way to stabilize a hydrofoil boat in roll is to angle the ends of hydrofoil 3 upward to pierce the water surface, as shown in Fig. 38 by a hydrofoil with midsection 165, and lifting end sections 167. In this case, fences 166 are needed to separate adjacent cavities, especially if hydrofoil section 167 is outfitted with different kinds of cavities above fence 166. Since the boat is now stabilized in roll, bow hydrofoil 163 could be replaced by bow hydrofoil 168 shown in Fig. 39, which is a surface piercing v-hydrofoil with positive dihedral. Hydrofoil 168 would provide the needed heave and pitch stability. In one embodiment, the hydrofoil is a main hydrofoil and an additional hydrofoil is mounted above the main hydrofoil for providing additional

lift for takeoff and for improving operation in waves.--

Paragraph beginning at line 24 on page 11 has been amended as follows:

-- Also shown in Fig. 39, are tip hydrofoils 169 for reducing the induced drag of the hydrofoil. These tip hydrofoils serve to increase the aspect ratio of the main hydrofoil by increasing its span and changing the flow pattern near each end. The tip hydrofoils can be angled up or down relative to the main hydrofoil, and can be either fully wetted or have a closed cavity on one or both surfaces. At least one surface of at least one tip hydrofoil has a closed cavity for reducing drag. The tip hydrofoils can also be placed at an angle of attack to the flow in order to generate a vortex that is opposite in direction to the usual tip vortex generated near each end of a main hydrofoil to reduce induced drag.--